CERTIFICATION OF APPROVAL

Planning for A Flexible Gas Processing Plant

by

Khairul Amilin B Muhammad Saberi

A project dissertation submitted to the
Chemical Engineering Programme
Universiti Teknologi PETRONAS
in partial fulfilment of the requirement for the
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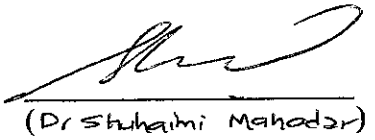
Approved by,



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TRONOH, PERAK

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CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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ABSTRACT

The main focus of planning for a flexible gas processing plant production in this project is regarding demethanizer. The demethanizer is a large stripping tower equipped with 40 two-sided valve trays and 3 chimney trays. It is also equipped with a conventional steam reboiler at the bottom, and three side pump around reboiler utilizing liquid draw offs from the chimney trays. Type of the boiler that was used as a heater was vertical thermosiphon reboiler. As ethane and heavier components are condensed during the cool down process, a large portion of the methane component is also condensed from the feed gas. The demethanizer and its related equipment are designed to strip this methane from the feed to form the overhead sales gas. The exact composition of the overhead will contain more or less ethane and CO_2, depending on the feedstock and the operating mode. The overhead temperature is at -64°C while the pressure is 2400 kPaG. The base is at 38°C and about 2420 kPaG. The demethanizer has two products. Product sales gas from the tower overhead is heated in the Feed Gas Cooler No.2 (T-403) and No. 1 (T-401) as in appendix 1, before going to the train of compressors. Ethane and heavier hydrocarbons from the tower bottom are pumped to deethanizer as a feed to Product Recovery Unit (PRU)

PROBLEM STATEMENT

Methane has many uses such as fuel in a gas turbine or steam boiler and used in industrial chemical processes and may be transported as a refrigerated liquid (liquefied natural gas, or LNG) The demethanizer and its related equipment are designed to strip this methane from the feed to form the overhead sales gas. The variation of components in the feed will affect the demethanizer efficiency. Therefore, the efficiency of the demethanizer will decrease due to the effect of the variations in the feed; thus, will decrease the production of methane

OBJECTIVE

The objective of this project is to increase the production of methane while increasing the efficiency of demethanizer by reducing the effect of the variation of composition in the feed.

SCOPE OF STUDY

The study of this project will cover on gas processing plant, specifically on Demethanizer. Variation of feed composition that come into Demethanizer and come out from Demethanizer will be analyzed. The function of scope of study is to focus and to limit the area of study on the relevant equipment only so that the variation of feed composition will be reduce, therefore, increase the production of methane. This project is feasible since we can modify the temperature and the pressure of the column to increase the production of methane. Modification of the operating parameter, (temperature and pressure) was due to the composition of the feed. If there is variation in the feed, adjustment towards operating parameter will be conducted.

LITERATURE REVIEW

Distillation is a process involving physical changes whereby a mixture of two or more miscible liquids can be separated into its components, no matter what is the ratio of the components in the mixture. It is a widely used process for separation and purification of products in refineries and chemical plant. First, we need to know a basic concept of distillation to have a better understanding of this project.

Vapor pressure

In general, the rates of vaporization increase with increase in temperature and vice versa. The pressure exerted by the vapor of liquid at a given temperature is called the vapor pressure of that liquid at the particular temperature. The vapor pressure increase with the increase in temperature and it decrease with the decrease in temperature. But, the variation in vapor pressure of a liquid is not in direct proportion to its temperature. The relationship of vapor pressure to the temperature is given by the following equation:

$\text{Log } P1 / P2 = k (1/T2 - 1/T1)$ where k is constant

Certain liquid evaporate faster and so they have higher vapor pressure, whereas some liquid evaporate slower hence they have lower vapor pressure. That is why different liquids have different vapor pressure, though they may be at the same temperature.
This is the ratio of the concentration ratios of two components in a binary mixture in one phase (vapor phase) to that in other phase (liquid phase) and is a measure of the separability of the components. Relative volatility is also known as the separability factor. It indicates how easy or difficult a separation will be.

Relative volatility, $\alpha_{ij} = \dfrac{(y_i / x_i)}{(y_j / x_j)}$ where: y_i = mole fraction of component 'i' in vapour.
x_i = mole fraction of component 'i' in liquid.

Thus if the relative volatility between 2 components is very close to one, it is an indication that they have very similar vapor pressure characteristics. This means that they have very similar boiling points and therefore, it will be difficult to separate the two components via distillation.

Boiling point

When a liquid is heated, its temperature starts rising and pressure also starts rising and consequently its vapor pressure also starts rising. If the heating is continued, a temperature will be reached when the vapor pressure of the liquid becomes equal to the pressure acting on the liquid surface (or equal to the atmospheric pressure, if the liquid being heated is exposed to the atmosphere) and the liquid starts to boil. This temperature is called boiling point (B.P) of that liquid at the particular pressure (i.e acting on the liquid surface)

When a liquid reaches its boiling point, bubbles can be seen forming inside the liquid and rising to the surface. Also, no matter how much heat is supplied to the liquid, the temperature does not rise further. This is because the heat supplied is used up in converting the liquid into the vapor and is called the latent heat.

Partial pressure

Now, consider a vapor or gas mixture of two components A & B having certain fixed volume at a certain given temperature. Suppose from this particular mixture the entire amount of one component (A) occupied the same volume at the same temperature (and component B is totally absent) then the pressure exerted by vapor pressure or gas is called partial pressure of A at a given time. Dalton established that the total pressure exerted by a gas mixture at a given temperature is equal to the sum of the partial pressures of its component at that temperature. Thus the total vapor pressure of a mixture of vapor or gases is the arithmetical sum of the partial pressure of its components. This is known as Dalton's Law of Partial Pressure and can be expressed as:

$P = P1 + P2 + P3 + \ldots\ldots\ldots P\,n$

Where P= total vapor pressure of the mixture

P1 = partial pressure of the first component

In a distillation process advantage is taken of these three concepts, i.e. vapor pressure, boiling point and partial pressure simultaneously at a given point in the following manner:

a) As we go on heating a liquid mixture, the vapor pressure of both components keeps on increasing.
b) The two components have different boiling point i.e. they have different vapor pressure at any given temperature i.e. one evaporates faster than other. In other words, one component is relatively far more volatile than the other.
c) On heating and partially vaporizing a binary mixture of liquids the vapor generated will have a higher concentration of the lighter component as compare to the concentration of the lighter component in the boiling liquid. If the mixture is cooled a little so as to condense it partially, the heavier component will tend to condense faster as compare to the lighter component, there by making the vapor mixture still richer in lighter component. This simultaneously partial vaporization and partial condensation is very important (as it makes the vapor richer in lighter component). Actually this happen on each tray of a column.

Feed to column

The liquid mixture to be separated by distillation is fed at a point somewhere in the middle of the column. The portion of the distillation column below the feed point is called the stripping section (where the lighter component is stripped from the liquid mixture) and the portion above the feed point is known as the rectification section (where the lighter component is rectified or purified). Usually the composition of feed is fixed. The actual location of the feed entry point is decided on the basis of the composition of the feed. The feed enters the column at such a point where the composition of liquid in

the region of column where the feed enters. This is to ensure smooth and efficient functioning of the column.

Demethanizer

The liquid which condenses when the inlet gas is chilled is a mixture of methane, ethane, propane, butane and gasoline. The volume of methane in the liquid is greater than all of the other hydrocarbons combined. The methane must be removed from the other hydrocarbons in order for them to be commercial value. The demethanizer is a fractionating tower in which methane is boiled from a liquid mixture of hydrocarbons. Methane gas is the overhead product, and the other liquid hydrocarbons are the bottom product. It differs from most fractionating towers in that have two or two more feed instead of a single feed stream that is typical of most fractionating towers. In addition, heat required to boil methane from the feed is supplied in reboilers at the bottom and also in a side stream reboiler, whereas a typical fractionators has only a bottom reboiler. A typical demethanizer is shown below in figure 1.

Flow is as follow:

The main feed stream comes from expander separator. A level control system on the separator regulates the flow of liquid. It enters demethanizer about midway up the tower. Since the operating pressure of demethanizer is much lower than that of the expander separator, some of the liquid will vaporize as its pressure is reduced in the separator level control valve. The liquid portion of the stream enters the demethanizer and flow across the trays or packing in the lower section of the tower. Up flowing gas on each tray boils the methane out of the liquid, so that by the time the liquid reaches the bottom of the tower, most of the methane has been boiled up as shown in figure 2. Heat to boil methane out of the down flowing liquid comes from bottom reboiler and side reboiler. Liquid entering side reboiler is withdrawn about $1/3^{rd}$ the way up to the tower. It flows through the reboiler, where it picks up heat from the inlet gas flowing through the tube side of the reboiler. Some of the liquid vaporizes when it is heated. The stream out of the reboiler returns to the tower below the tray from which it was withdrawn.

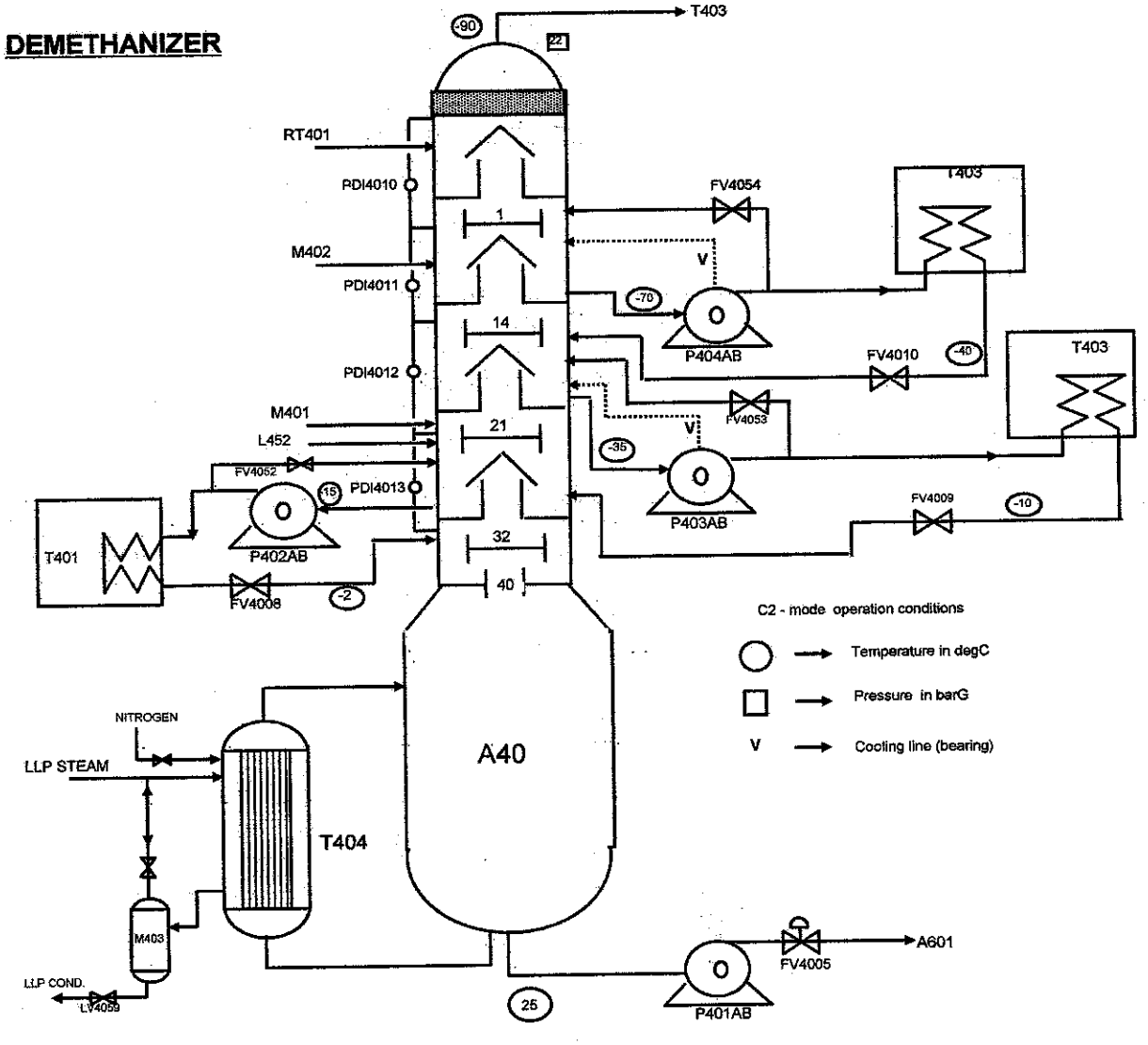


Figure 1: Diagram of Demethanizer

Liquid from the bottom tray flows to the bottom reboiler; where it is heated by inlet gas, which results in some vaporization. The gas which forms flows up the tower and liquid

that remains is the bottom product. It is pumped through a heater to fractional towers to separate it into ethane, propane, butane and gasoline. Product flow is regulated with a level control system.

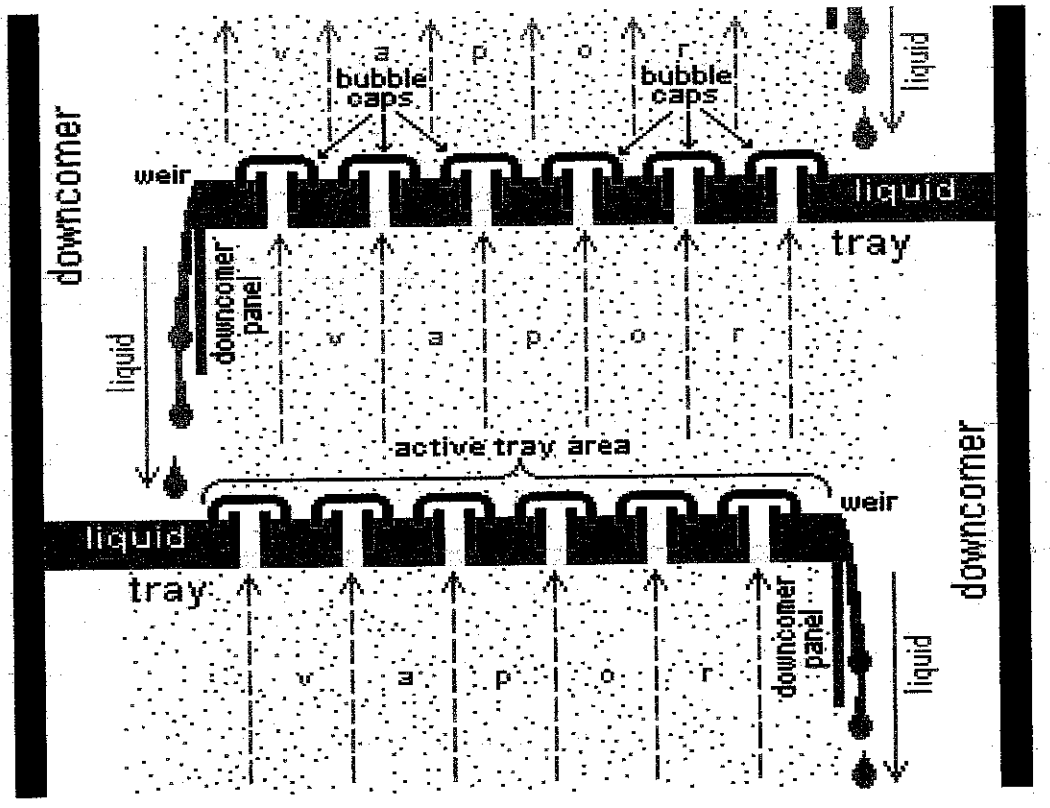


Figure 2 : Diagram of flow in Demethanizer

The vapor portion of the stream from the expander separator that enters the demethanizer flows upward. It bubbles through the packing or liquid on each tray. Most of the C2 and heavier hydrocarbons in the gas are condensed by the liquid on the trays, so that gas leaving the top tray is mostly methane. It flows into the separator section on the top of the tower. The stream out of the expander also enters this separator. It is a mixture of gas and liquid. The gas combines with gas from the top tray and exits the tower at the top and flows through the gas-gas exchanger and compressors and leaves the plant. Liquid in the

stream from the expander falls to the bottom of the separator and flows to the top tray of the tower. It serves as reflux to the tower.

Ideally, the top product from a demethanizer is pure methane. In practice, however, the methane will contain some ethane. This is undesirable because the purpose of cryogenic plant is to recover ethane (and other hydrocarbons) in the liquid product at the bottom of the demethanizer. In typical fractionating towers, the overhead gas is condensed in reflux condensers, and part of the liquid is pumped back to the top tray for reflux. The reflux liquid composition is the same as that of the top product which is usually at least 98% pure. The ethane content of the gas leaving the demethanizer can be reduced by adding reflux to the tower. This is accomplishing by condensing part of the overhead gas and returning the liquid to the top for reflux. Reflux facilities are installed when the extra ethane recovery justifies the expensed of the reflux facilities. The temperature of a gas leaving a demethanizer is about -90^0 C to 100^0 C.

Auxiliary Equipment for Demethanizer

1) Feed Preheater

Most distillation column has a feed preheater. This is a heat exchanger to heat the feed to a desired temperature before it enters the column. The heating medium may be either steam or some other hot process stream (to recover waste heat and conserve energy).

2) Reboiler

For distillation the liquid at the bottom of the column has to be boiled. To accomplish this, a column is provided with a reboiler, which is a heat exchanger, using a heating medium to provide heat to bottom of the column. Most common heating is steam. A reboiler is usually a separate unit located adjacent to the column. A distillation column is driven by a reboiler. It is a heat duty of a reboiler, supplemented by the heat content (enthalpy) of the feed that provides the energy to make a split between light and heavy components.

3) Bottom pumps

It is used to withdraw the bottom product. If forced circulation reboiler is used, then a stream from this pump discharge is used for forced circulation through the reboiler.

4) Demister or Mist Eliminator

Entrainment of liquid droplets occurs when drops of liquid suspended in vapor are carried up into the next tray or into the overhead vapor. Entrained droplets may have some of the heavier component. Entrainment can be undesirable when the overhead product is required as a dry vapor. Some columns are provided with demisters at the top to remove the entrained liquid from the overhead vapor.

Significant process variables

1) Pressure

Pressure is a variable that the operator rarely needs to change. Column usually equipped with control valves that regulate the pressure automatically. Uncontrolled pressure changes lower the quality of all products.

2) Flow rates

Based on the requirement flow rates may be varied within a limit, depending on types of the column. Increased feed flow will increase the vapor load on the column and also the load on reboiler.

3) Temperature

The composition of a product determines its boiling temperature. If the column top temperature is maintained at a value higher than the design temperature (column pressure same) the overhead product will be off specification and have more of heavier component. If the reflux is increased without increasing the bottom temperature correspondingly, the bottoms will tend to become richer in lighter component.

4) Level

Level is controlled at column bottom. If a column is operating in steady state, these levels remain constant.

TYPES OF COLUMNS AND COLUMN INTERNALS

Distillation columns are basically of two types, namely tray (plate) columns and packed columns. Function of both types of columns is the same, but each type has certain advantages and disadvantages. The choice of the types of column depends on the nature of the process fluid mixture, column diameter etc.

TRAY COLUMN

Tray columns are vertical hollow cylindrical shells, which have a large number of trays or plates fitted inside at regular intervals. Trays are of many types.

TYPES OF TRAYS IN A COLUMN

Most common types of trays used are:

1. Bubble cap trays
2. Valve trays
3. Sieve trays
4. Grid trays
5. Shower deck trays

Now we shall discuss various types of tray designs and their functioning a little more in detail.

BUBBLE CAP TRAYS

A number of trays are places inside the column, fitted with a device called bubble caps that forces the rising vapor to bubble through the liquid in each of the tray.

A bubble cap consists of the following part:

The riser allows vapor to come through the tray from the tray below. Each riser is covered with a bubble cap, which is held in position by means of a spider support.

Slots or teeth are designed to be submerging in the liquid level, so that the bubbles of vapor are formed in the liquid.

The smaller the bubbles the greater is the area for vapor liquid contact.

If the vapor velocity is too slow, the bubbles formed are large and fractionation is poor on the tray.

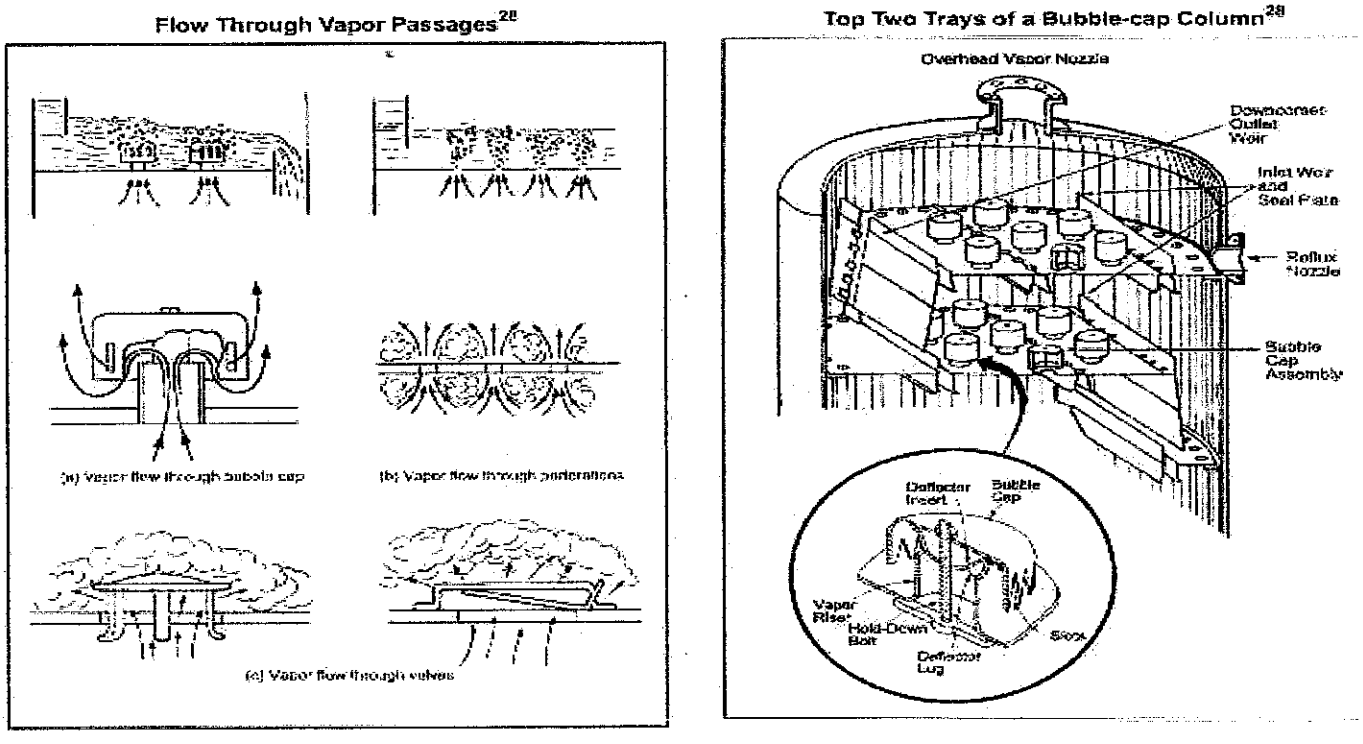


Figure 3: flow through vapor passages & top two trays of a bubble-cap column

If the velocity is too fast the vapor blows through the liquid, without proper contact. Bubble formation is poor if the velocity of the vapor is too fast. For good fractionation the velocity

of the vapor must be moderate.

If dirt collects on the teeth or slots, the vapor gets obstructed and poor fractionation results.

Thus, in a bubble cap tray, the vapor flows up through center riser (also called" uptaken") reverse flow under the cap, passes downwards through the annual s between riser and cap, and finally passes into the liquid through a series of opening or slots in the lower side of the cap.

DOWN COMER

Down comer is passage way through which which liquids flows from one tray to the next lower tray. The down comers carry reflux down the column.

Inlet down comer is the one, which brings down the liquid from the tray above.

Outlet down comer is the one, which allows liquid to run down.The function of the different models of bubble caps is in principle the same.There are round and oblong bubble caps.The advantage of bubble cap trays is that a better fractionation is obtained.

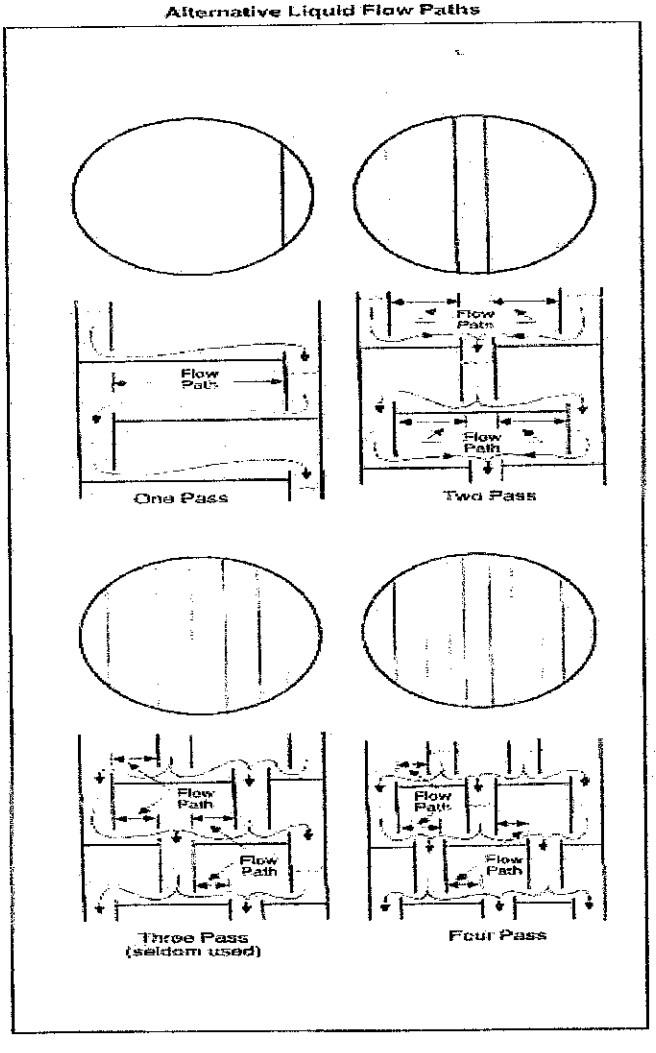


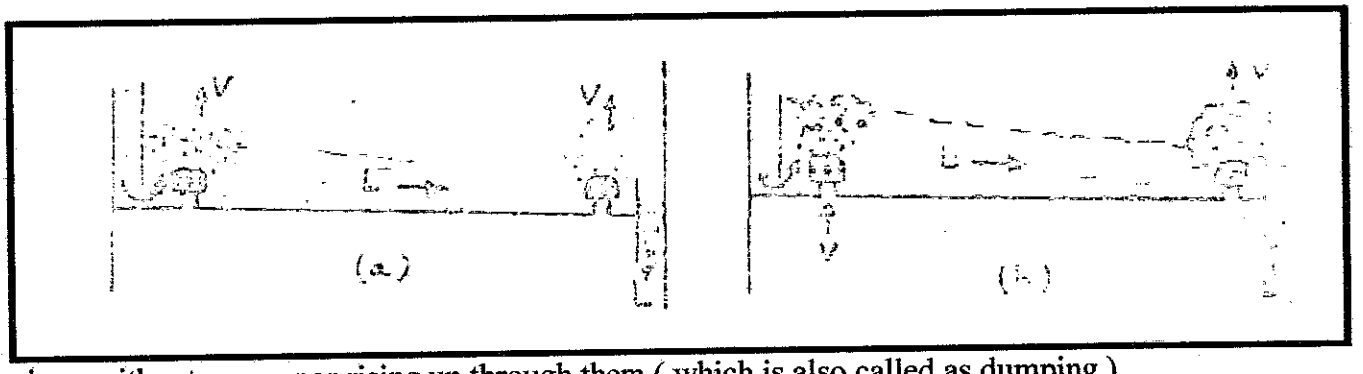
Figure 4 :Alternatives liquid flow path

However the disadvantage of bubble cap tray is the fall in the liquid level across the width of the column that occurs especially in the bigger trays.

A fall in the liquid level across the width of the bubble cap tray will occur with heavy use. The liquid unable to flow off quickly will accumulate so that the level on the trays is no longer horizontal.

The rising vapor will naturally pass through these caps, which offer least resistance , that is to say those towards the outlet downcomer.The overloading of these causes the blasting away of the liquid round the risers , the vapor rises without proper fractionation.

On the other hand towards the inlet downcomer the liquid overflows down through the



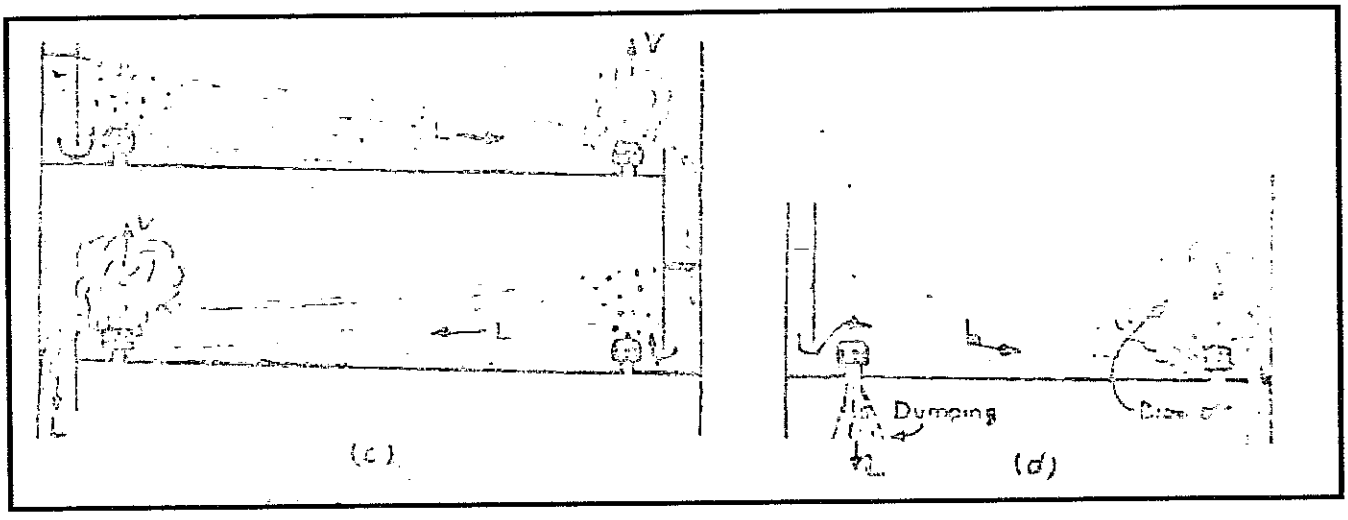
risers without any vapor rising up through them (which is also called as dumping)

Figure 5 : normal operation & build up increasing

a - Normal operation b – Build up increasing

REDUCING THE SLOPE IN THE LIQUID LEVEL ON A BUBBLE CAP TRAY.

Double supply and discharge : The liquid flows to the middle of the tray. The distance between the raised edges has decreased, reducing the slope of the liquid level.In order to overcome this problem the cascade model of a bubble cap tray has been put into practice.



c- Bare minimum stability

d – Dumping

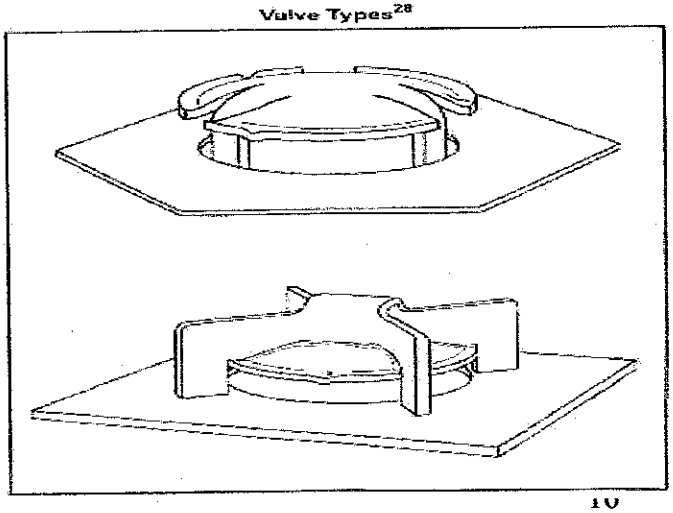
Figure 6: bare minimum stability & dumping

CASCADE MODEL OF A BUBBLE CAP TRAYS

model of a bubble cap trays are used in large diameter distillation columns to minimize the formation of slope in the liquid level, thereby eliminating " dumping".

Because of the design of tray , the liquid level has no slope due to overflow partitions which divide the tray floor into sections.

Use of this trays require taller columns .These trays occupy more space as compared to the ordinary bubble cap trays.



VALVE TRAYS

These trays have simple round perforated holes or orifices which contain movable "valves "that can float and provide variable orifices of non-circular shape.The liquid tends to drain through these orifices but is

prevented by upward flowing action of of the vapor.Thus when the vapor

Figure 7 : valve types

flow is less the liquid will tend to drain through these orifices but this is prevented as the valves will adjust orifice opening in such a way that the draining or weeping is minimized.The valve tends to close as the vapor flow reduces , varying the total orifice area to maintain a dynamic pressure balance across the tray. (fig)

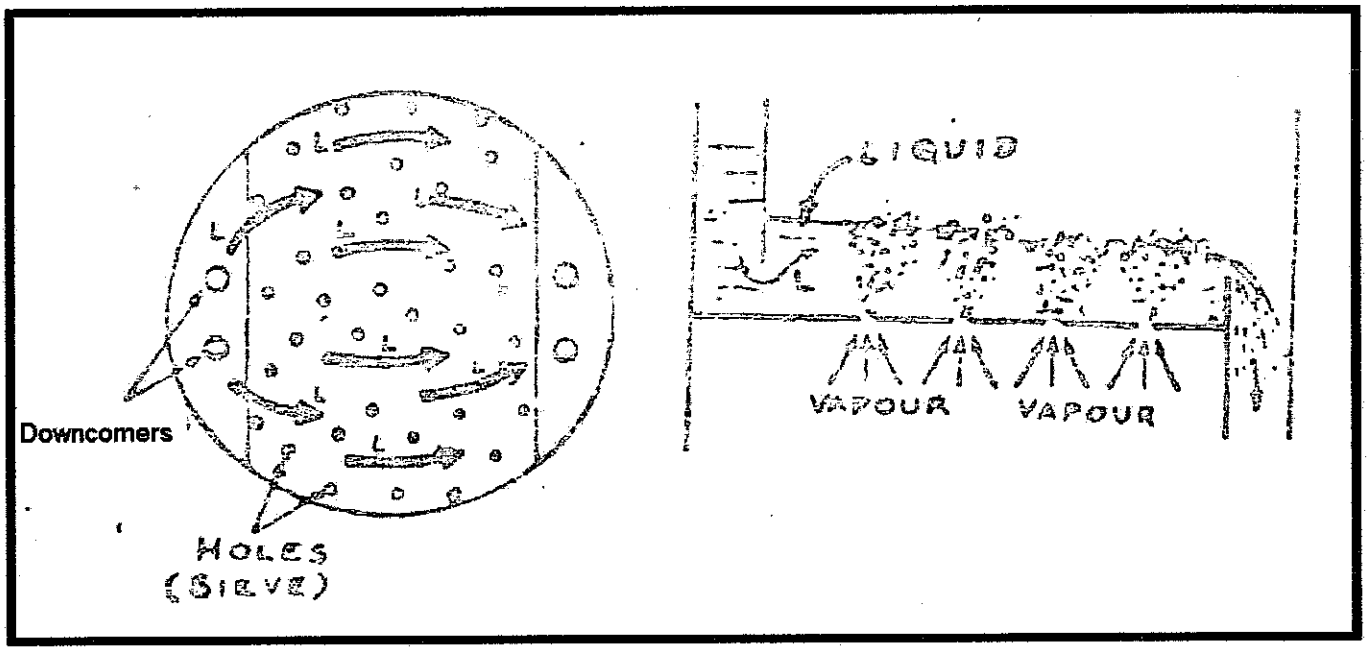
SIEVE TRAYS

A sieve tray is made of a light metal sheet with a large number of circular hole drilled through it.

Vapor rises through these holes on the tray floor and bubbles through liquid level on the tray in fairly uniform manner.The sieve trays may be designed with or without down-comers.If the downcomers are used the weirs are also provided to maintain a liquid level. If the trays are provided with down- comers , the liquid flows across the tray floor over a weir through down-comer to the tray below.

When no down- comers are provided , the liquid head ion the tray forces liquid counter 0 current through these holes and onto the tray below.The liquid flow forms random patterns in draining and does not dorm continuous streamlets from each hole.

Figure 8 : sieve trays



GRID TRAYS

These are simple in design and consist of parallel metallic strips or grids which extend uniformly over the cross section of the column. (fig).These trays are arranged in the column such that the strips are grids are are 90 ° to those of the tray above and below.

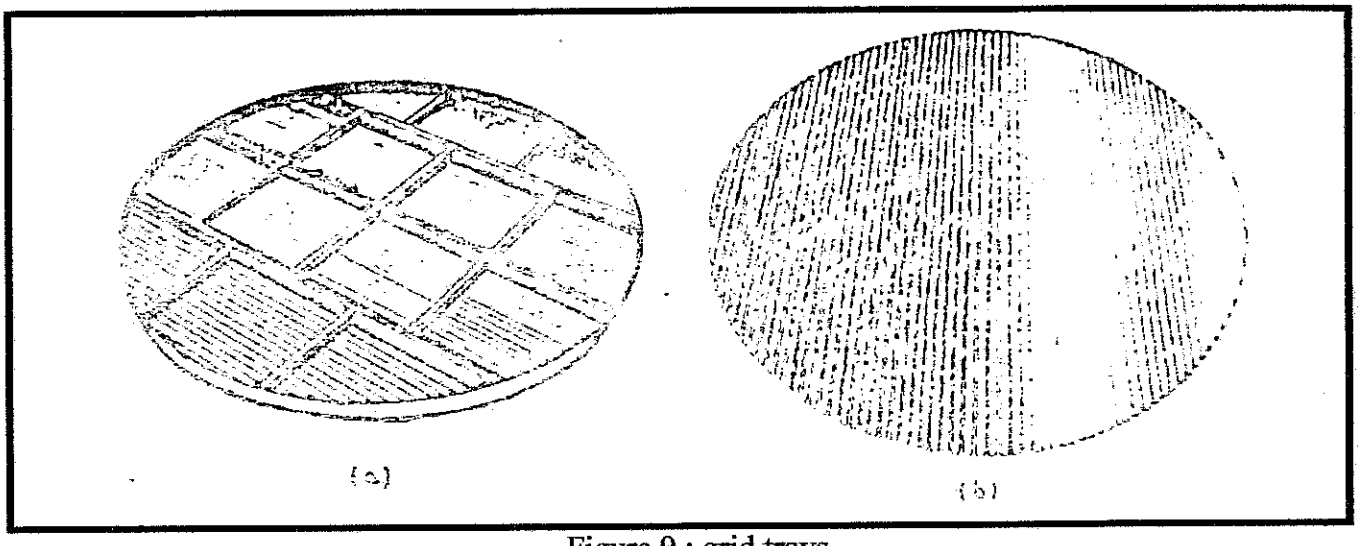


Figure 9 : grid trays

Sometimes the metallic strips are not continuous , but the tray has a series of slots .These type of tray is known as turbo – grid tray.

The grid trays give greater capacity, less pressure drop than the conventional bubble-cap tray design .Grid trays were primarily designed for high capacity service in the petroleum industry and they have the additional advantage of low cost of construction.

The Grid trays are usually not provided with down-comers. Functioning of the grid trays is

similar to sieve trays.

SHOWER DECK TRAYS AND BAFFLE TRAYS

A counter flow tray often used for contacting vapor with liquid containing solids is the shower-deck tray or the baffle tray.

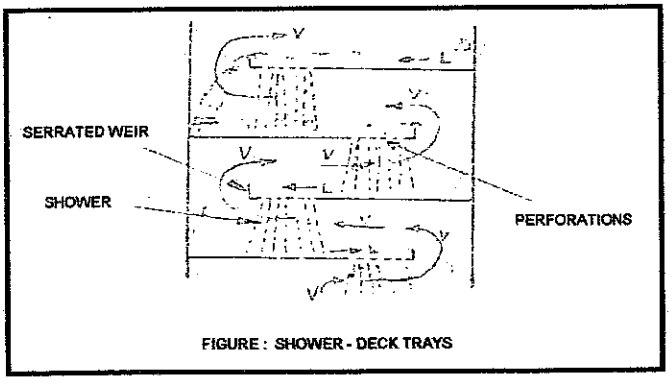


FIGURE : SHOWER - DECK TRAYS

The shower-deck tray is segmental or half-moon in shape and the area near the edge has perforation through

which the liquid showers onto the tray below.

Figure 10 : shower-deck trays

The vapor traversing in a zigzag path on its way up comes in intimate contact with the shower of falling liquid. Thus the enrichment takes place between the trays and not on the trays.

The baffle tray is more or less, similar to a shower deck tray except that it has no perforations. Baffle trays are, usually sloped slightly in the direction of flow of liquid .The vapor comes in contact with the liquid as it showers from the tray. The baffle trays may be provided with a serrated lip or weir at the edge of the tray to improve distribution of liquid in the tower.

The baffle tray operates with liquid dispersed and gas as the continuous phase, and is used more in heat transfer applications

The baffle tray operates with liquid dispersed and gas as the continuous phase, and is used more in heat transfer applications. Shower deck trays offer Iess pressure drop.

In addition to the types of trays discussed above, many other vapor liquid contacting devices are used in an attempt to attain desired efficiency. Some of the other type of trays are - Koch tray, ripple tray, Kittel tray , Benturi tray , etc. However, the most commonly used type of trays are bubble-cap trays, valve trays, sieve trays and grid trays.

(Please note that in a column in which both vapor and liquid have to pass through the same passage ways ,that is in a column using sieve trays or grid trays without any downcomers, the trays behave as a packed section)

Now we shall discuss the packed columns and various types of packings used after a comparative study of column trays in adjoining chart.

COMPARITIVE STUDY OF COLUMN TRAYS

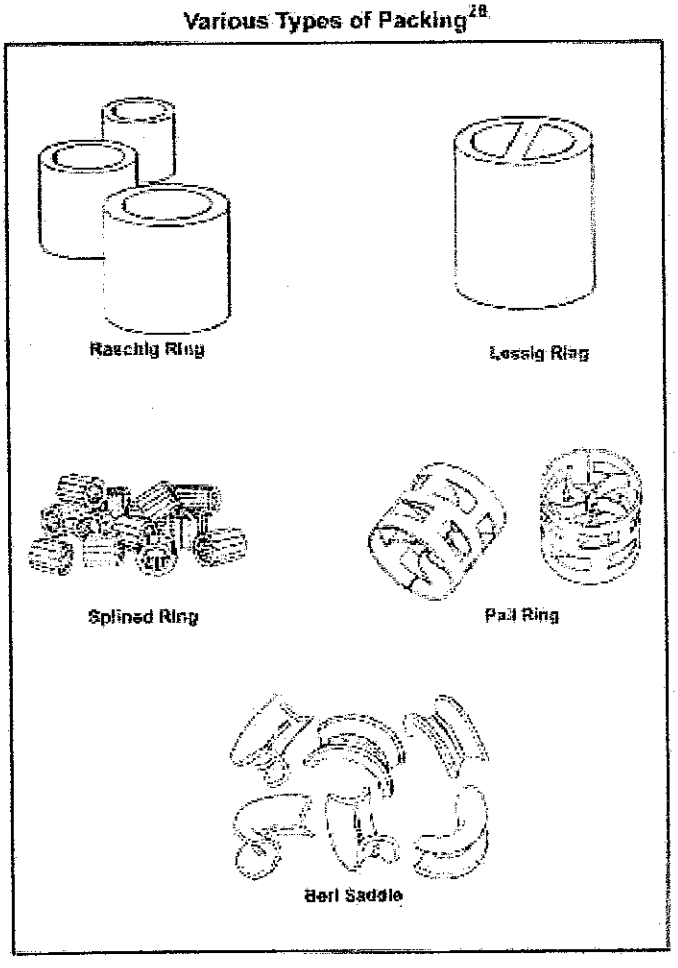
TYPE OF TRAY	CAPACITY	EFFICIENCY	ENTRAINMENT	FLEXIBILITY	APPLICATIONS
Bubble Cap	Moderately high Maintains efficiency	High	More than Sieve tray	Overloading leads to dumping	All services except for coking & Polymer formation.
Sieve tray with down-comer	More than bubble cap at more than 60 % capacity	High as bubble cap at more than 60 % capacity	One third of bubble cap tray	- Not suitable for variable load - Below 60 % tray weeps	For high capacity or continuous services -Handles suspended solids
Sieve tray with out down-comer	Same as bubble cap tray at 50 – 100 % capacity	- Not as high as bubble cap - Falls below 60 % capacity	One third of bubble cap tray	Not flexible	-High capacity can be maintained on continuous service -Handles suspended crystal and small solid particles
Flexi tray or Valve tray	High	High	Higher than bubble cap tray	High	- Suitable for variable load - Low pressure drop

Table 1 : Comparitive study of column trays

PACKED COLUMNS

Sometimes packed columns are used instead of trays.These columns are used in order to bring about intimate contact between vaporand liquid. The height of a packed column depends on the rate of mass transfer through the liquidand the vapor phases.In these columns the vapor flows steadily up and the reflux (liquid) steadily down , giving a true counter-current system in contrast to the conditions in tray type columns, where the process of enrichment is stagewise. Packing can be divided in three classes:

(1) Broken Solids, (2) Shaped packings , and (3) Grids or sieves.



The principal requirements for choosing appropriate packings are

1) It must be chemically inert to the fluids in the column.
2) It must be strong without excessive weight,

3) It must contain adequate passages for both streams without excessive liquid hold-up or pressure drop.

4) It must provide good contact between gas and liquid.

Figure 11 : various types of packing

Broken solids are the cheapest form of packing but are usually not used in distillation columns because blockage often occurs if the fluids contain suspended solids. Shaped packings, such as raschig rings, lessing rings, berl saddles, intalex saddles, pall rings,etc are most commonly used packing materials. (Fig)Usually the column beds are filled with randomly -oriented packing material, but in some cases the packing may be positioned, thus a packed column is a simple device compared with the tray column.

A typical column consists of a cylindrical shell having two or more packed beds. Each packed bed has a support tray for retaining packing material. A hold-down tray is fixed over the packings to hold the packing in position and prevent them from flying.

Uniform initial distribution of liquid at the top of every packed bed is essential for efficient column operation. This is accomplished by a device that spreads the liquid uniformly across the top of the packing. This device is called distributor.

The distributor below the feed point is called the feed distributor and the one below reflux entry point (i.e. on the top most bed) is called reflux distributor. (See -figure)

It is found,that a single-point distribution in a 12 - inch column with ¾ - inch parking requires 10 feet of bed before achieving uniform distribution across the bed. It is also noticed that liquid has a tendency to migrate towards the column wall.

With the use of a distributor, a shorter bed functions better or as effectively as a much taller packed bed without a distributor.The liquid once distributed over the top of the packing flows in thin films over all the packing surface down the column.The film becomes thicker in some places and thinner in other places.Thus the liquid accumulates

and flows along some localized paths through the packing.This effect is known as channeling, partial plugging or blockage of packing by the solids entrained in the liquid stream may also cause channeling.

Channeling is most severe in columns packed with stacked packings, less severe in dumped packing with regular shaped rings.

Channeling is the chief reason for poor performance of large packed columns.

The main drawback with a single large packed bed is that liquid tends to channel .To avoid this , usually the large beds are broken into two or more smaller beds with redistributors between beds for efficient performance of the column.

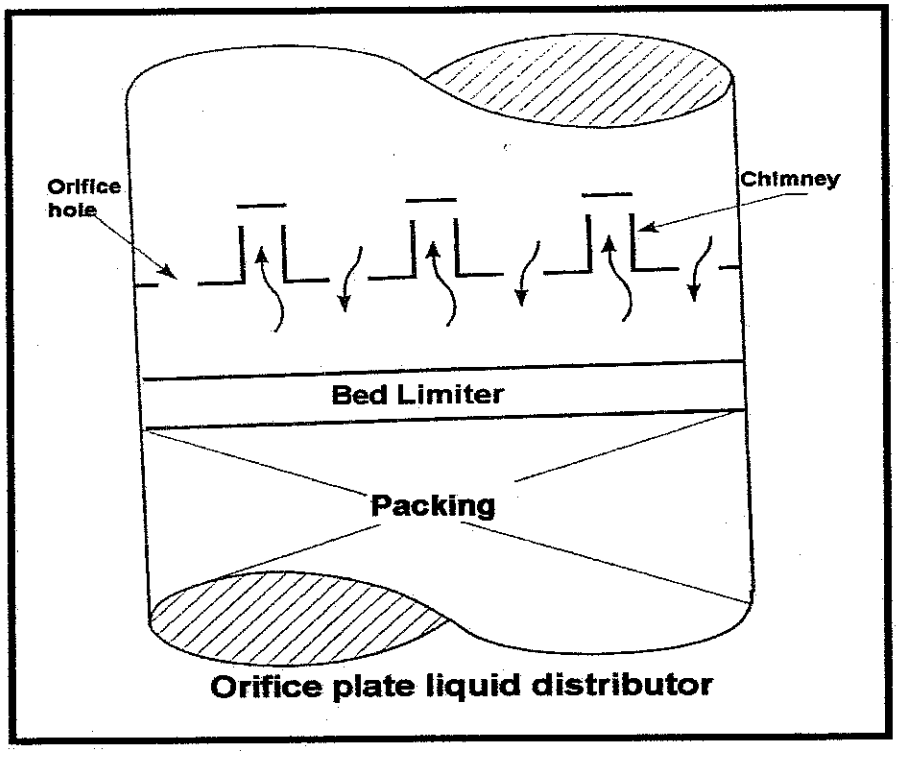


Figure 12: orifice plate liquid distributo

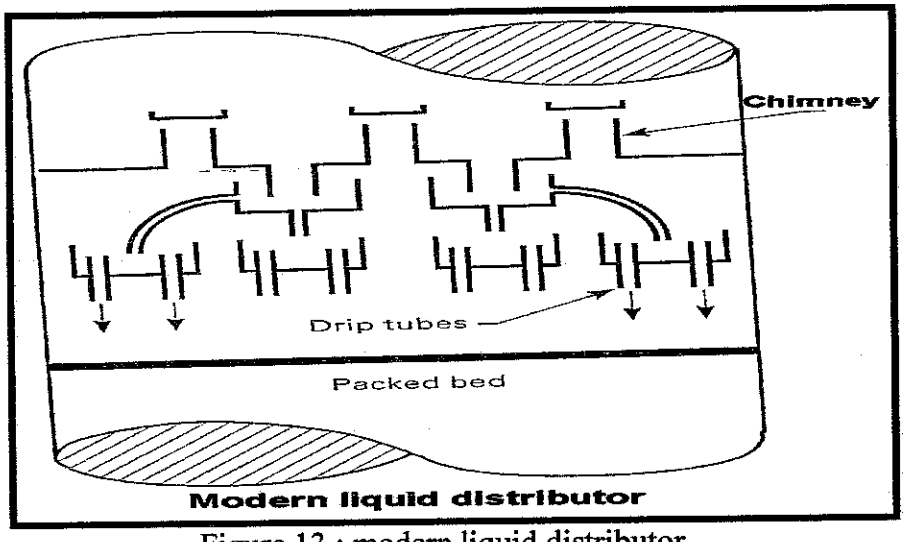
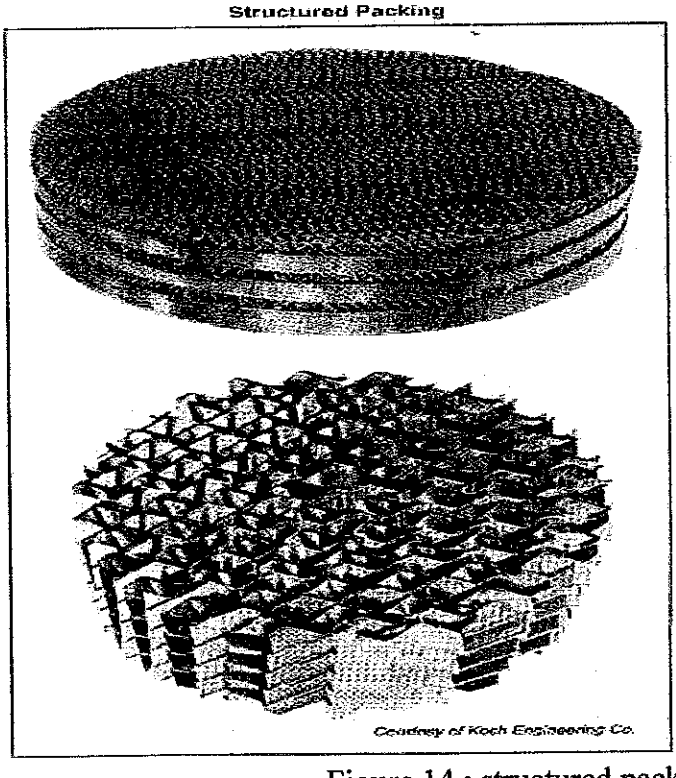


Figure 13 : modern liquid distributor



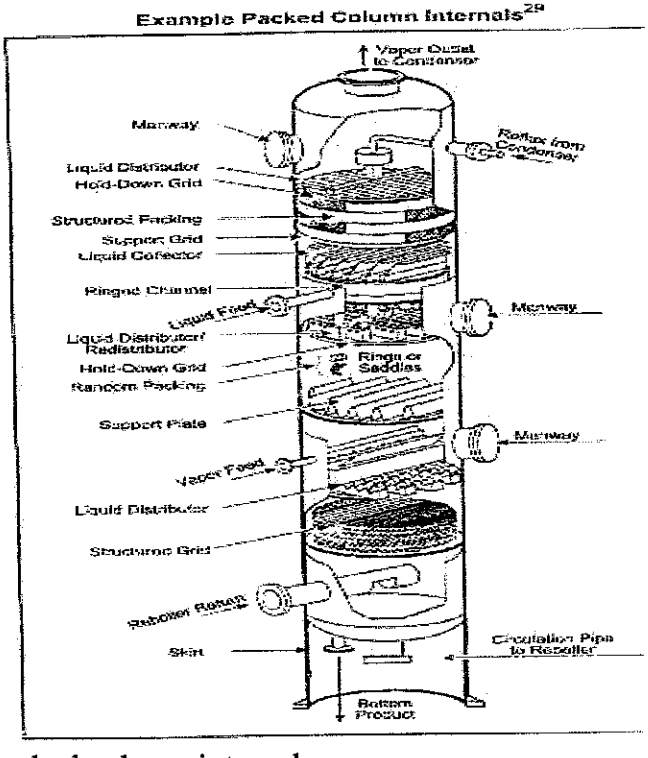


Figure 14 : structured packing & packed column internal

ADVANTAGES OF PACKED COLUMNS

1. For columns less than 2.0 ft diameter , packings are usually cheaper than plates unless alloy metal packings are required.Also in thin tray columns the number of bubble caps or valves will be very less hence packing will serve better.
2. Acids and other corrosive materials can be handled in packed columns because construction of packing can be ceramic , carbon or other resistance materials (PP , Teflon etc)
3. Packed columns have lower pressure drop per unit height.
4. Liquids tending to foam may be handled more effectively in packed columns because of relatively low degree of liquid agitation by the gas.
5. Hold up of liquids is quite low in packed columns.
6. This is advantageous when the liquid is thermally sensitive.

DISADVANTAGES OF PACKED COLUMNS

1. Some packing materials are subjected to easy breakage during filling them into the column or resulting from thermal expansion and contraction (The column to be packed is first filled with water , ceramic rings are then dropped into water to prevent breakage during filling.)
2. Flexibility for load changes are limited.
3. High liquid rates can be handled more economically in tray columns than in packed ones.
4. Slightly contaminated liquids may easily block packing.

5. Channeling of liquid and vapor streams may occur, thereby making separation less effective.

6. Distribution of liquid in packed tower is quite difficult.

Less liquid rates lead to incomplete wetting of the column packings , thus decreasing contacting efficiency.

TYPES OF REBOILER

The types of reboilers are;

- Vertical thermosiphon
- Horizontal thermosiphon
- Forced circulation
- Kettle
- Internal reboiler

Vertical thermosiphon

- The most common type of reboiler in distillation practice.
- It achieves high heat transfer rates.
- Low fouling tendency
- Low residence time of boiling material in the heated zone.
- Compact

- Low capital cost.

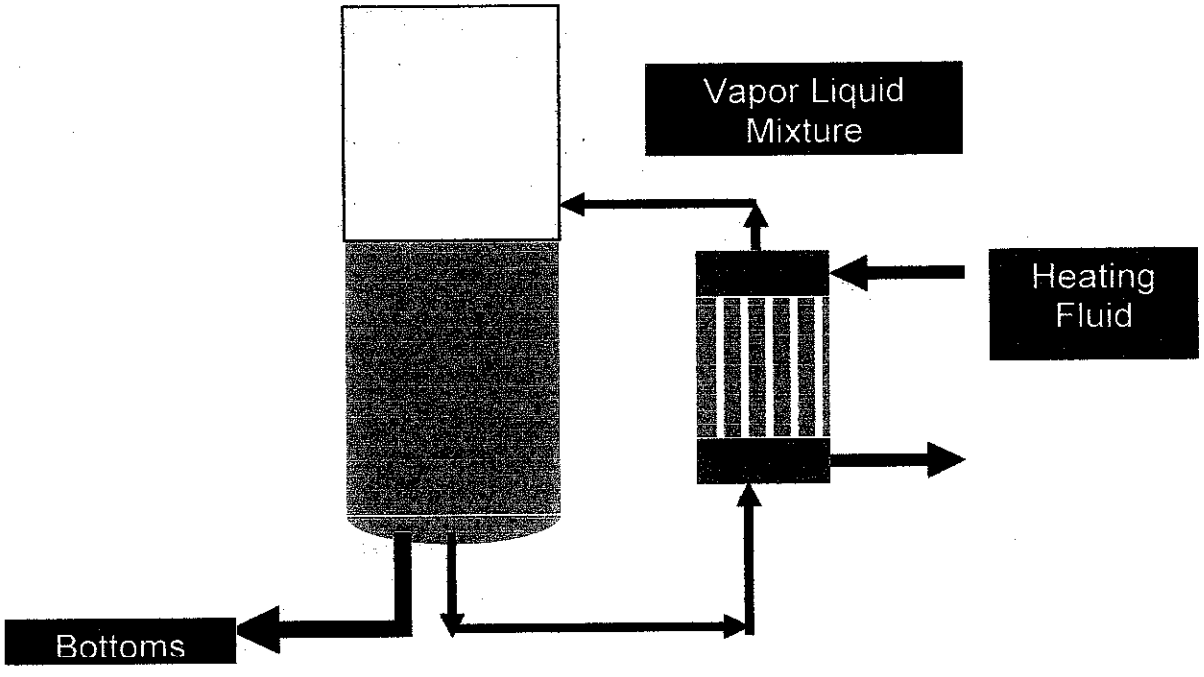


Figure 15 :vertical thermosiphon

Horizontal Thermosiphon Reboiler

- Require more piping compared to vertical type reboiler.
- Higher fouling tendency (the boiling fluid in the shell)
- Lower reliability
- Higher cost

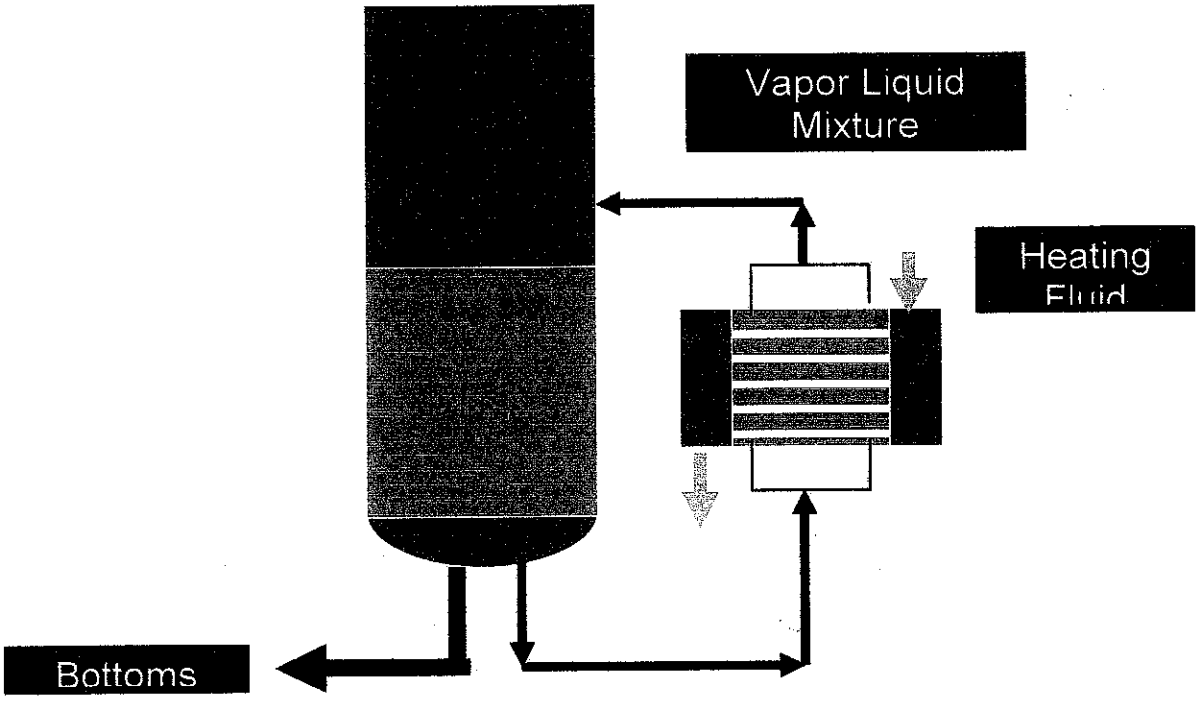


Figure 16 : Horizontal Thermosiphon Reboiler

Forced Circulation Reboiler

It is preferred when;

- Highly fouling or solid containing system. Forced circulation can achieve higher velocities & can operate at lower vaporization rates per pass than others.
- In fired heaters
- In highly viscous systems (>25 cP). Where liquid must be pushed through the reboiler.
- Where reboiler is located a fair distance from the column.
- In vacuum system (< 4 psia). Thermosiphon reboilers are often troublesome

Kettle Reboilers

- Low heat transfer rate
- High fouling tendency
- Spacious
- Expensive

They are preferred when;

- Insufficient vertical head in the column
- The heat transfer area required is large
- Instabilities are anticipated
- Frequent cleaning is anticipated
- Desired liquid in the reboiler outlet is minimize
- Operation near the critical pressure, where reliability is a primary consideration.

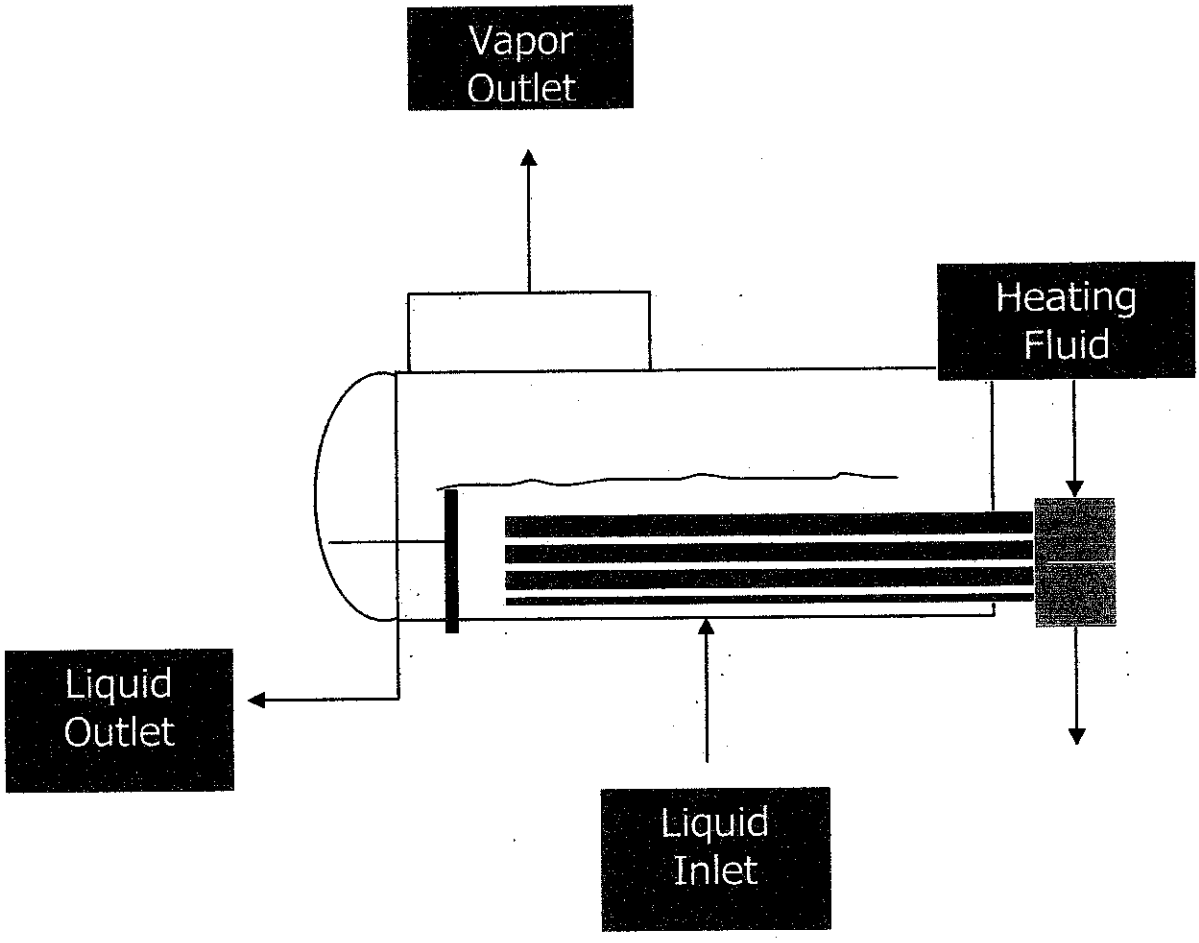


Figure 17 :kettle reboiler

Internal Reboilers

- Require increased in column diameter.
- Less attractive in foaming & vacuum services.
- They are used where;
  - Batch distillation, where the tube bundles can easily be fitted into the batch drum, and periodic cleaning can be easily accommodated.
  - Very low heat duty clean services, where column diameter is large due to other considerations, and the reboiler tube bundle required is small.

Principles of Tube-Side Boiling -Circulation-

- Natural circulation occurs because of the density difference between the liquid in the bottom of the column and the two-phase mixture in the heated tubes.
- Liquid flows from the bottom sump of the column to the reboiler base, where it is distributed to the tubes.
- The feed leg contains resistances to flow, such as valves, orifices, expansion & contraction pieces, and pump in the case of forced circulation.
- When the liquid arrives at the reboiler base, it is usually sub-cooled because of the effect of static pressure & heat losses from the line.
- When the liquid enters the tubes, heat is applied to the liquid.
- Initially the sub-cooled liquid is heated to its boiling point by sensible heat transfer only. After the boiling point is reached, vaporization begins & two phase flow regimes are established.
- Circulation rate through the reboiler is fixed by the driving force & the resistance to flow.
- In a fixed piping system, it is a function of the liquid level in the reboiler sump in the case of natural circulation, and pump in forced circulation.

Principles of Tube-Side Boiling -Boiling-

- Tube side boiling takes place in one out of two mechanisms, nucleate and convective.
- Nucleate pool boiling occurs when the heated surface is surrounded by a large volume of liquid, with nucleation taking place at the tube wall.
- In order for nucleate boiling to occur, the temperature of the heated wall must exceed the saturation temperature of the boiling liquid.
- In order to maintain nucleate boiling, the vapor bubbles on the surface must be surrounded by a layer of superheated liquid.

- If the liquid in contact with the wall is not sufficiently superheated to sustain bubble nucleation, then heat removal is by convection through the liquid film, with evaporation occurring at the liquid vapor interface of the vapor core.
- This is often the dominant mechanism in thermosiphon reboilers, particularly

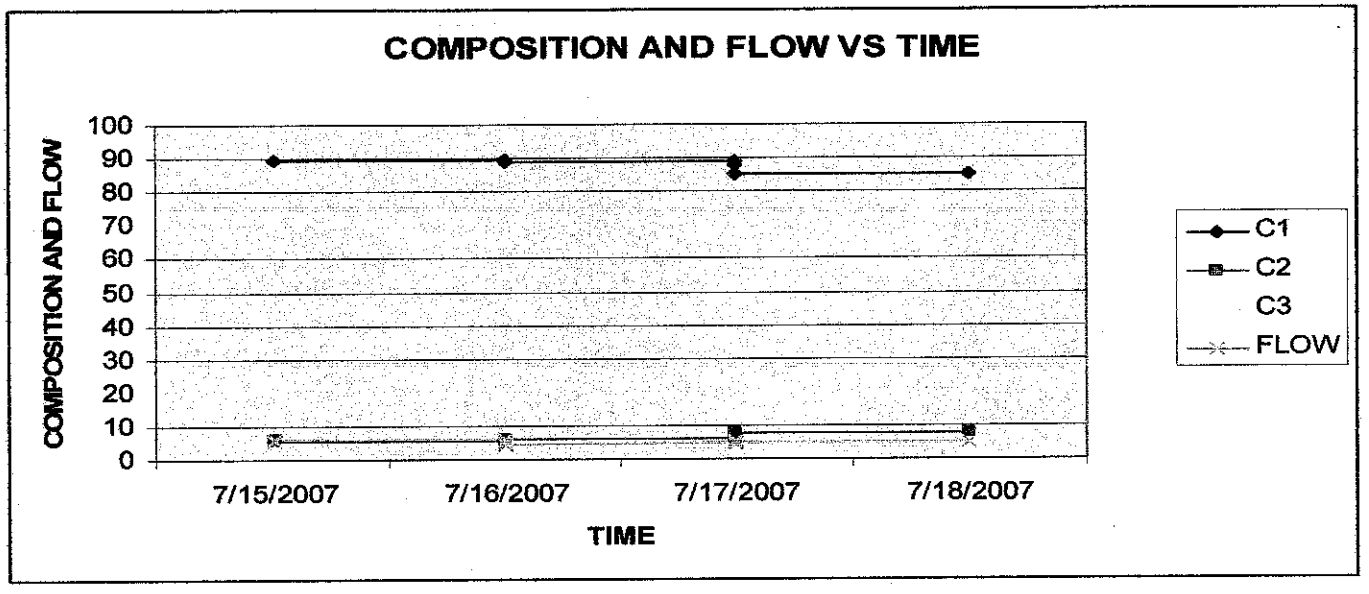
METHODOLOGY

First of all, I need to get familiarize with the gas processing plant production process especially on demethanizer. This is important because from the process, I can get a better view on what really happen in the demethanizer and have a general idea on how to solve the problem regarding the variation of composition in the feed into the demethanizer.

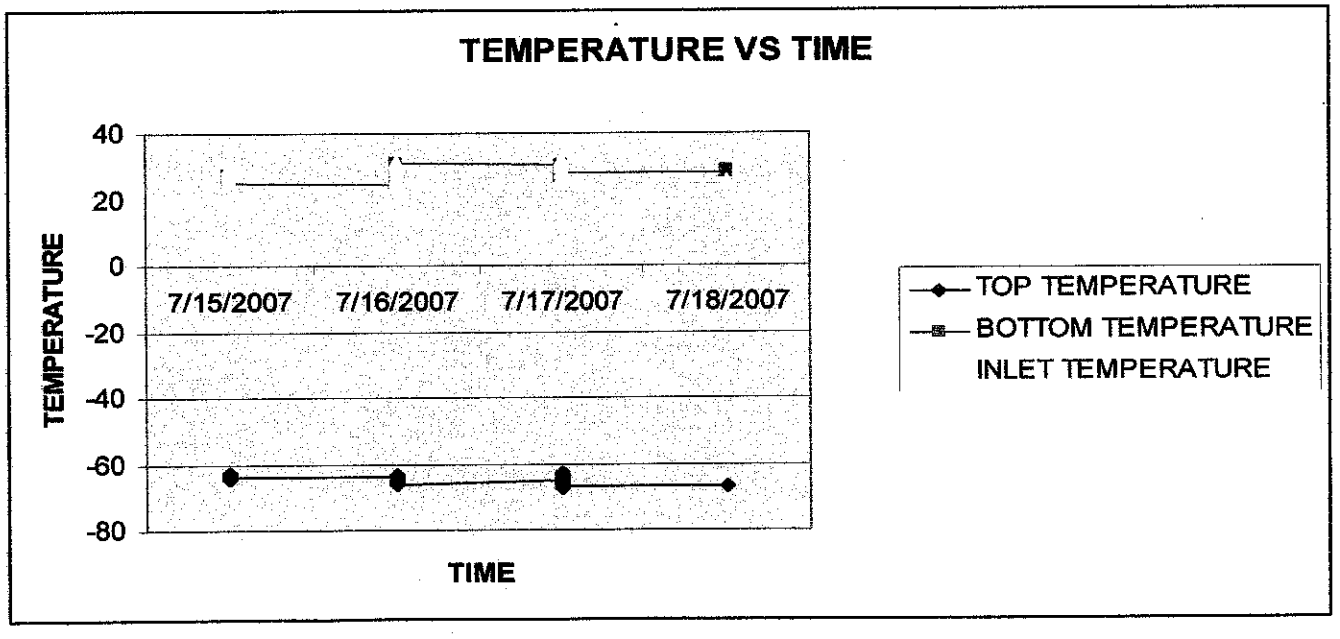
Then, I will focus on my problem which is variation of feed composition. Before I can analyze my problem, I need to know well about the in and out feed composition of demethanizer. After that, I will gather all the data regarding the feed composition using software call LIMS. Using LIMS, I can find out the composition of the feed, the density of each components and the molecular weight of the components.

Lastly, I will do the simulation part using HYSIS, Icon or Gams. This simulation will determine whether the process flow in the feed is stable when I do the modification. I can stimulate the equipment so that I can observe whether there is a variation or not in the feed. When the process flow is stable, means, there is no variation in the feed come into demethanizer, and then I will apply the adjustment. Therefore, I can increase the efficiency of the demethanizer.

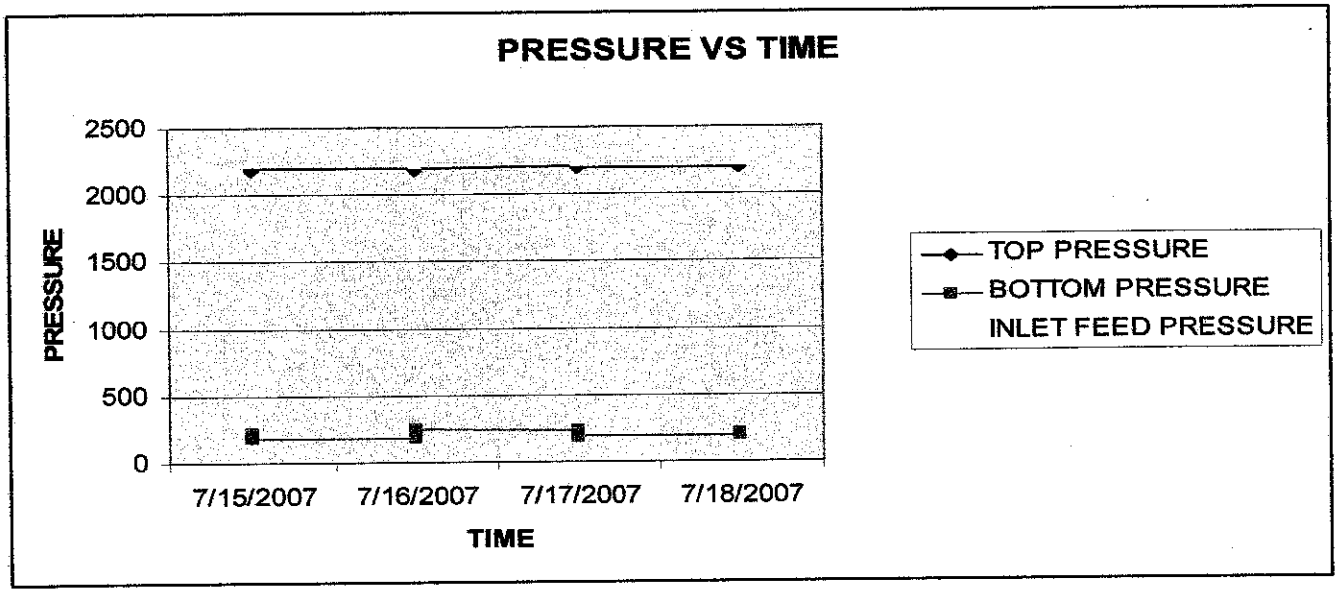
RESULT AND DISCUSSION



Graph 1: Composition and Flow vs Time



Graph 2: Temperature vs Time



Graph 3: Pressure vs Time

Heat duty of reboiler, $Q=mc\ (T_2-T_1)$ where; m =mass flow Cp=specific heat capacity

Examples from collected data:

DATE	T1	T2	m
1 july 07, 6:00	17.91748	27.87326	4899.148

Table 2: Example of data

Cp = 1.99

Cp gets from data sheet of reboiler.

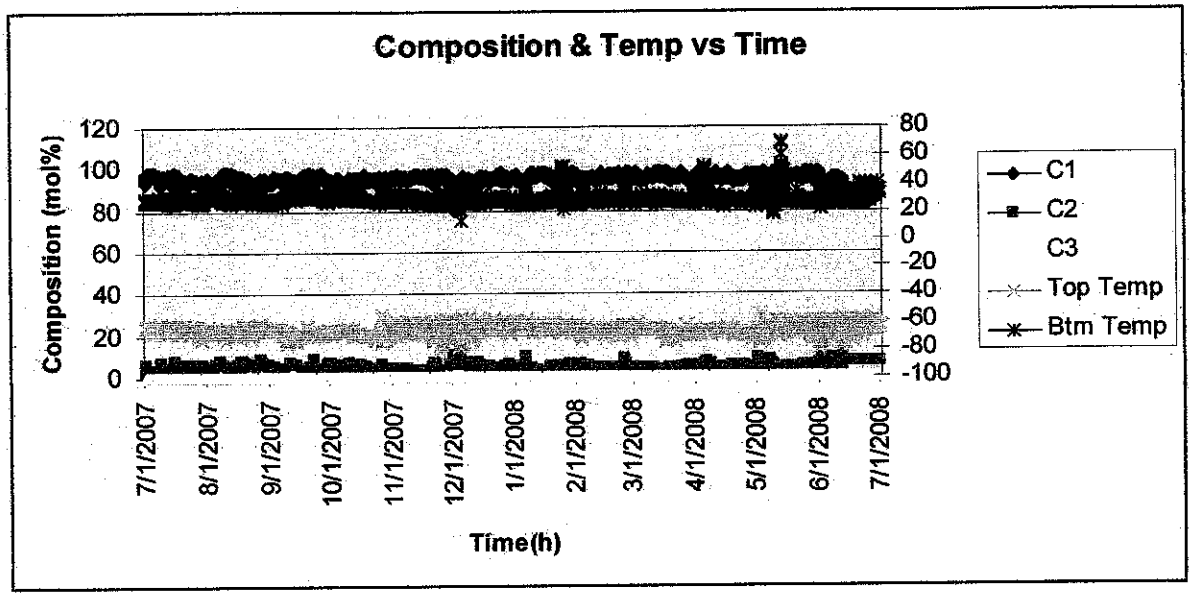
Therefore;

$Q= mc\ (T_2-T_1)$

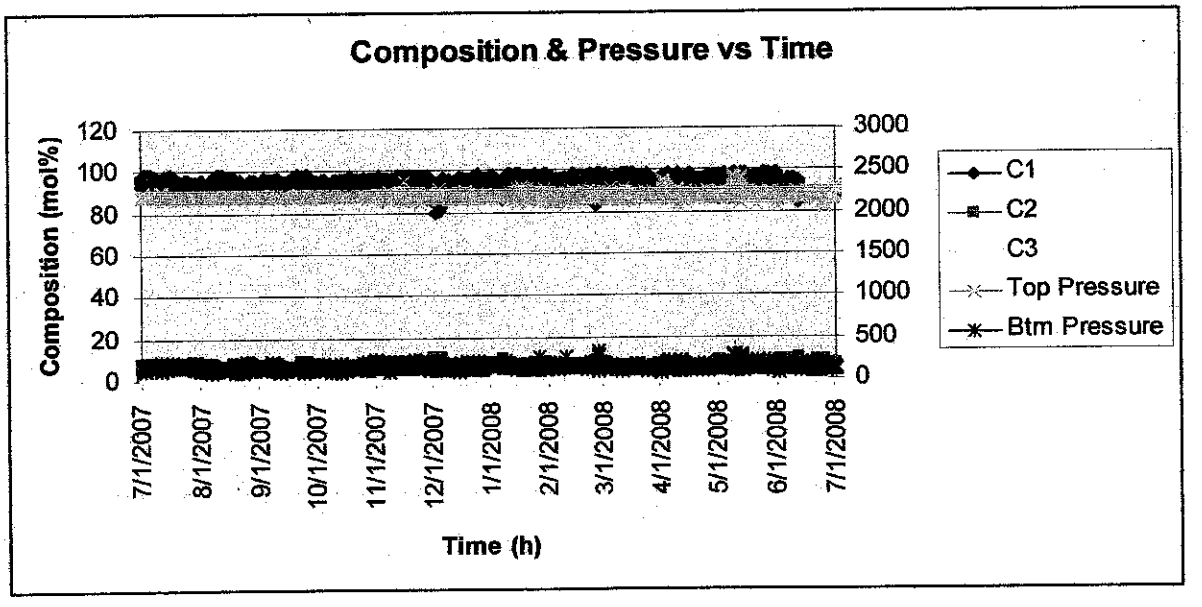
$= (4899.148)\ (1.99)\ (27.87326 - 17.91748)$

$= 97061.931$ kJ

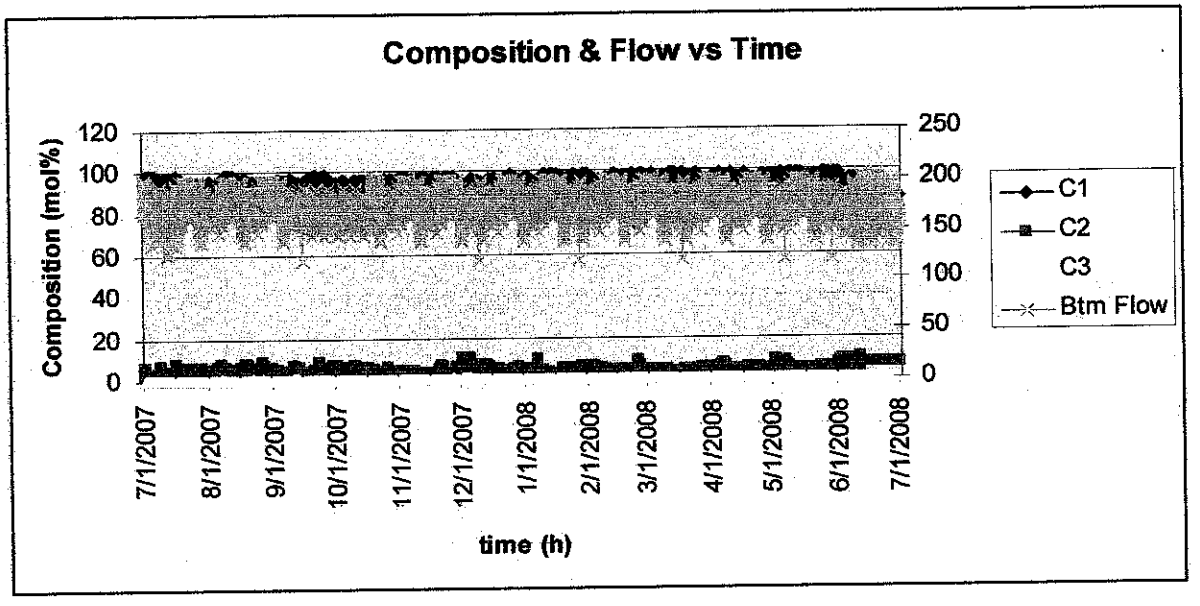
The integration of the variables and composition;



Graph 4: composition & temperature vs time



Graph 5: composition & pressure vs time



Graph 6 : composition & flow vs time

The effect of the variation of the composition in the feed will affects the process variables such as the pressure of the column and the temperature of the column. This effect of variation of composition in the feed usually will increase the pressure of the column. Basically, pressure is a variable that rarely need to change because, columns are usually equipped with control valves that regulate the pressure automatically. Uncontrolled pressure change, especially from the variation of the composition in the feed, will lower the quality of the products. The increasing of pressure in the column will increase the vapor velocity; therefore the higher will be the entrainment. Entrainment is inherent in the process of distillation. In the column, vapor flows up and liquid flows down the column. When the vapor travels upwards it drags or carries over with it some amount of liquid droplets. This process takes place continuously, which is known as entrainment.

Excessive vapor flow in the column causes the excessive carryover of liquid from tray below to tray above, i.e. instead of only vapor traveling to the tray above, liquid also

travels. This reduces the efficiency of fractional and the products usually don't meet the required specification. Some amount of entrainment is unavoidable. Care is taken in the design stage of the column to minimize entrainment by spacing the trays at sufficient distance. Proper spacing between trays lets the drops of liquid fallout of the rising vapor. Reducing vapor flow also helps to reduce entrainment.

Besides pressure, temperature also will change. Although, we cannot see clearly the difference from graph 2, but the variation composition will affects the temperature if the other parameter and the other factor is constant. The effect of variation of the composition in the feed will increase the temperature. This is because; the composition of the product determines its boiling point. For an example, methane has a boiling point of 42°C while ethane has a boiling point of 72°C. Therefore, if there is variation of composition in the feed, especially when ethane has more than the required specification, the boiling point of the composition will also change. If the top column temperature is maintained at a value higher than the design temperature (column pressure same), the overhead product will be off specification and have more of heavier components.

A rise in boiling temperature fluid called Elevated Boiling Point may occur due to temperature change. Possible causes are increase in column operating pressure and depletion in low boiling component. The possible effect is the reboiler temperature pinch thus reducing heat transfer due to reduction in temperature difference between process and heating stream while the signs are increase in liquid boiling temperature and increase in steam flow to maintain specified heating requirement.

The incoming flow into the demethanizer will also be affected. This is due to the variation of composition in the feed. From graph 1, it is clearly that the flow will decrease with time as the composition of methane is reduce meanwhile the composition of ethane is increase. For example, if there is more of heavier hydrocarbon such as propane in the feed, the flow definitely will be slow. Based on the requirement flow rates may be varied within a limit, depending on the type of the column. Increased feed flow will increase the

vapor load on the column and also the load of the reboiler. Suppose we increase the vapor flow, maintaining liquid flow the same. This can be done by in practice by increasing the heat input to reboiler. By this action, vapor to liquid ratio will increase through the column. Now consider any typical the vapor tray in the column, in general, it will receive liquid from tray above it and vapor from the tray below it. After mixing of these two streams in these trays, equilibrium will be established and vapor from this tray will go to the tray above it, and liquid to the tray below it. As we go upwards in the distillation column, both these trays (liquid and vapor stream) get progressively richer and richer in lighter components.

Now, when vapor load is increased, the tray composition slowly becomes richer in heavier components because vapor to this tray is coming from the tray below and hence has more of heavier component compared to the liquid coming from the tray above it as a result both liquid and vapor leaving the tray also become richer in heavier component. This happens in both the sections of the column (stripping and rectification sections). This action is beneficial for stripping since the function of stripping section column is to make the bottoms richer in the heavier component. Thus, increasing vapor load alone has an effect of decreasing top purity.

On the other hand, if the liquid flow is increased, keeping vapor flow the same, it has an effect of increasing liquid to vapor flow ratio and thus, by similar reasoning improves top purity. Increased feed flow due to variation of composition in the feed will increase the vapor load on the column. Thus, will create a problem in the column called vapor overloading. Below is the illustration of basic process in the column:

Each tray has 2 conduits, one on each side, called 'down comers'. Down comer is a passage way through which liquids flows from one tray to the next lower tray. The down comers carry reflux down the column using gravity principle. A weir on the tray ensures that there is always some liquid (holdup) on the tray and is designed such that the holdup is at a suitable height, e.g. such that the bubble caps are covered by liquid. Being lighter, vapour flows up the column and is forced to pass through the liquid, via the openings on each tray. The area allowed for the passage of vapour on each tray is called the active tray

area. Also, if the flow of liquid through the column is increased, the downcomers might eventually fail to carry away all the liquid flowing on the trays. The liquid thus backs up in the downcomer of the upper tray until the former is full. The liquid then begins to back up on the upper tray itself. This happens on all upper trays. Finally liquid is blown up the column by the vapor so much that unfractionated liquid carried over the top of the column with the overhead vapor and ultimately comes to accumulator. The column is said to be puking, this phenomenon is more likely to occur when the liquid has tendency to foam too much. This type of liquid overloading may often be recognized by violent pressure swings, sharp temperature variations and large variations of level at the bottom and at the reflux accumulator. Generally the remedy against liquid overloading is a sharp reduction in the feed and on reflux flow rates. On many occasions vapor and liquid overloading will occur simultaneously. Furthermore, overloading may not be the only cause. Fouling, scaling and clogging of trays' may also cause the similar type of disturbance.

Vapor overloading caused by variation of composition in the feed. If the boil up rate is increased by increasing feed flow rate continuously, the vapor will eventually become so high that the liquid is blown off the process. The required intimate contact between liquid and vapor is lost and large amount of unfractionated liquid is carried up the column due to excessive entrainment. This will interfere with the separation process. This type of overloading can be recognized by a gradually increasing pressure drop between bottom and top of the column. Therefore, it is clear that the variation of composition in the feed will cause a serious problem.

Besides create problem to the column, reboiler also will be affected.

Liquid Level : Low liquid level will diminish the driving force for liquid circulation thus reducing heat transfer coefficient. Vapor produced can be in the form of superheated thus significantly curtailing heat transfer.High liquid level can also diminish performance of a

vertical thermosyphon reboiler. The greater circulation reduces the percentage of liquid that is vaporized. Allowing liquid level to rise above the boiler discharge into the column can suppress boiling and destabilize reboiler hydraulically.

Surging : Sudden and often violent, waves of vapor followed by a paused in boil up. It is common when feed contains a high weight fraction of high-boiling components. Overheating can deplete the column base of the low-boiling component. At this point, a film of high boiling liquid will cover the reboiler tubes, reducing heat Transfer as well as the boil up rates. This later led to the dumping of liquid (on column trays or in liquid packing) thus supplying lower boiling components to the column base.Boiling and circulation then resume. However, a sudden surge of steam flow and boil up can again quickly deplete the base of the low-boiling components, repeating the cycle.

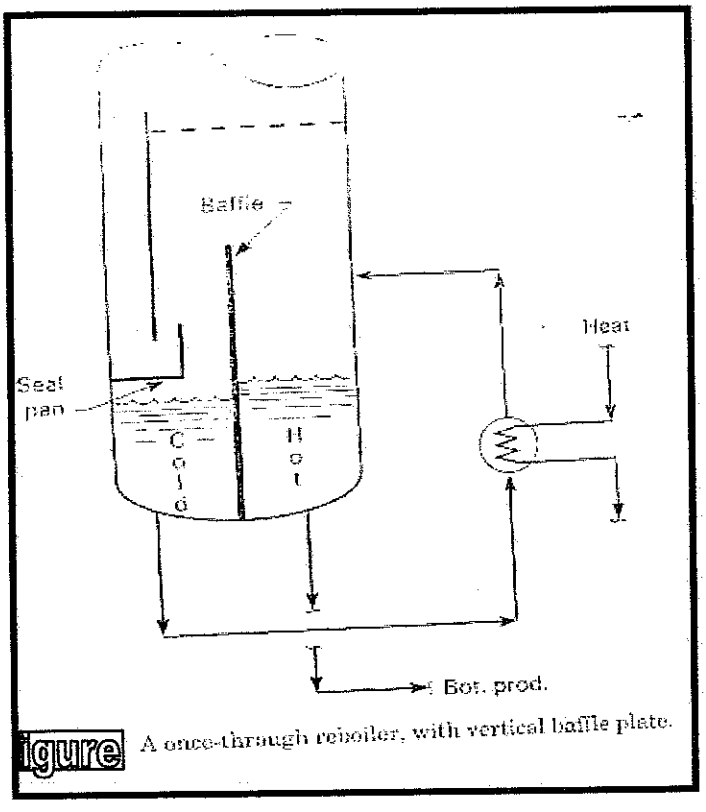


Figure 18 : reboiler with vertical baffle plate.

Fouling : Corrosion and material sublimation can cause fouling. Process condensate can reeze if coolant temperature is too low such as during process upset where heavy material can be driven overhead. Such freeze up can plug condensate drain and flood the condenser, coat the tubes and reduce heat transfer or restrict vapor flow. Coolant side fouling is more common where low water velocity can allow silt to accumulate and a

high water outlet temperature can led to mineral deposition on heat transfer surfaces. The extent of fouling can be estimated by the change in heat transfer coefficient.

Vapour Binding : Vapour or air pocket can block of heat transfer area from the coolant, especially at start up. This is more likely if the coolant leaves from the bottom of the shell.

Inert Blanketing : Presence of inert gases in condenser can also block heat transfer area thus reducing heat transfer taking place. Condensers that are operated flooded for pressure control are prone to accumulating inert gas, if it is not shunted via a bypass.

Vent System Overload : If a condenser becomes overload, a back pressure may build up from the vent line or vent condenser resulting in hot vapor flow through the vent line.

Condensate: Process condensate backing up into condenser and cover heat.

Flooding :transfer area thus reducing heat transfer

RECOMMENDATION

Few recommendations to decrease the effect of the variation of the composition in the inlet feed:

i. Make sure the source of the inlet feed meet the composition specification..
ii. Make sure that all the equipment functioning well. For examples, chloride scrubber must be in good condition so that there will be no slippage of chloride into the feed.

Few recommendations to increase the efficiency of the demethanizer (increasing the efficiency of demethanizer tray), therefore, increase the production of methane:

i. The outlet weir height; higher weirs raise the liquid level, increase the interfacial area and contact time giving improved efficiencies.
ii. The liquid flow path length; longer path lengths enhance efficiency, as liquid mixing is less able to flatten out the axial liquid composition profile developing, across the entire tray.
iii. The surface tension and surface tension gradients; a lower surface tension increases the interfacial area and hence efficiency

CONCLUSION

In conclusion, the increasing of production methane can be achieved by increasing the efficiency of demethanizer while decreasing the effect of the variation of composition in the inlet feed. This can be done by maintaining the process variables well.

REFERENCES

1. McCabe, W.L, Smith, J.C and Harriot, P., " Unit Operations of Chemical Engineering," New York, 4th Edition, McGraw-Hill Book Company, 1980
2. Thiele, E.W., "Computation of Distillation," ind.Eng.Chem., Vol 25, PP289-95,1932.
3. Underwood, A.J.V., "Fractional Distillation of Multicomponent Mixtures," Chem.Eng.Prog., Vol 44:p603, 1948.
4. Lecture Notes of Separation Process 1 & 2.
5. Seader J. D., & Henley E. J. (1998). *Separation Process Principles*. New York: John Wiley and Sons.
6. Sinnott R. K. (1993). *Coulson and Richardson's Chemical Engineering (Volume 6* Great Britain: Butterworth-Heineman.
7. Douglass J. M. (1988). *Conceptual Design of Chemical Processes*. Singapore: McGraw Hill International Editions.

Geankoplis C. J. (2003). *Transport Processes and Separation*

8. Perry R. H. (1997). *Perry's Chemical Engineers' Handbook. Process Principles*
9. *(Includes Unit Operation)*. New Jersey: Prentice Hall.New York: McGraw- Hill.